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Spatial and temporal distribution of Ostracoda (Crustacea) assemblages in Lake Kartal (Köyceğiz, Muğla, Turkey)

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ABSTRACT
This study was performed in a typical cirque Lake Kartal (1903m a.s.l.) located on Mount Sandıras (Çiçekbaba). Spatial and temporal distribution, abundance and habitat preferences of ostracod assemblages were studied in of Lake Kartal in Turkey. Two ostracod taxa (*Candona neglecta* and *Psychrodromus olivaceus*) were identified from Lake Kartal during May 2008 to October 2008. Among all ostracod species, the most common and abundant in Lake Kartal was *Candona neglecta* (56%, 912 individuals). During this study, other microcrustacean fauna were qualitatively evaluated. Some main physico-chemical parameters were also analyzed. Kartal lake is a freshwater (salinity between 0.0-0.1‰) alkaline (pH between 8.25-8.94) and shallow (2 m) lake. According to Spearman correlation analysis, there was significant relationship between ostracod species and temparature in Lake Kartal. There are a significant relationship between number of ostracod species and altitude in Lake Kartal and also other adjacent lakes.

Keywords: Cladocera, Copepoda, Fauna, Lake Kartal, Ostracoda.

1. Introduction

Lake Kartal is an important drinkable water resource for local people and settlements. Therefore, it should be kept carefully protected in the near future. Many aquatic drinkable and habitable water resources and the living species within these aquatic habitats are becoming increasingly susceptible to both natural and environmental changes. Conservation strategies must be prepared for the protection of aquatic life and sustainable use of the water resources by administrative authorities.

According to Attila *et al.* [1] there are modern glaciers in the South-eastern part of the Taurus Mountains (located between the Mediterranean Region and the South East Region of Turkey). However, there is available evidence indicating glacial activities belonging to last ice age on Sandıras (2295 m) Mountain. However, the summit of this mountain is not covered with mass of snow and ice during the summer seasons for many years. Glacial deposits in these mountains are well preserved. A cirque lake is a water body that forms in U-shaped depression valleys. These valleys are usually created by valley glacier with erosion. Water collects in these depressions, it is called to as a cirque lake. Cirque lakes are small lakes (with extreme physicochemical conditions) which are less complex than lowland lakes. Temperature, high UV radiation and lack of nutrients are important limiting factors in a highland lake. Therefore, both plant and animal species have adapted in many different ways to deal with this challenging environment of a cirque lake. There have been many studies performed on the fauna and flora of lowland region lakes of Turkey. However, limited studies have been performed on microcrustacean (Cladocera, Copepoda Ostracoda) fauna of high mountain lakes [2, 3, 4, 5, 6, 7, 8]. In this study, the determination of some microcrustacean species and investigation of their ecological characteristics was targeted in Lake Kartal. Composition and abundance of micro-crustaceans was determined by means of material collected during the ice-free periods in 2008. The aim of this paper is to assess species richness and composition of Ostracoda (partially covering copepods and cladocerans) assemblages in alpine Lake Kartal, examine the relationship between the occurrence of species and environmental variables, and compare the microcrustacean (Ostracoda, Copepoda and Cladocera) fauna with the different lakes in adjacent area.

2. Material and Methods

2.1 Site description: Mountain Lake Kartal is located (37° 05' 48.70" N, 28° 51' 04.30 "E) in Köyceğiz District, Muğla Province in the Turkey. At the same time, Lake Kartal is located on Mount Sandıras (Çiçekbaba) at 1904 m a.s.l. (see Fig 1 and Fig 2). Its approximate surface area and maximum depth are 2 ha and 2 m, respectively. The lake has an outlet. Lake outlet (Uzun Creek) is fed by the lake. The lake is covered by an ice layer from October until June. Lake is a typical cirque lake. Lake Kartal was formed by Pleistocene glacial activity [9]. Lake Kartal may be shallow with freeze-thaw weathering and glacial erosion process. The lake shape is like a spoon. The area around the lake is dominated with Anatolian Black Pine (*Pinus nigra pallasiana* (Lamb.) Holmboe) trees. A small eagle population lives on the rocks. Therefore the lake is called "Eagle (Kartal) Lake". Around the lake approximately 200 plant species have been identified [10]. A few fish species also live in the lake [10]. Villagers used lake waters as drinking water for themselves and their animals.

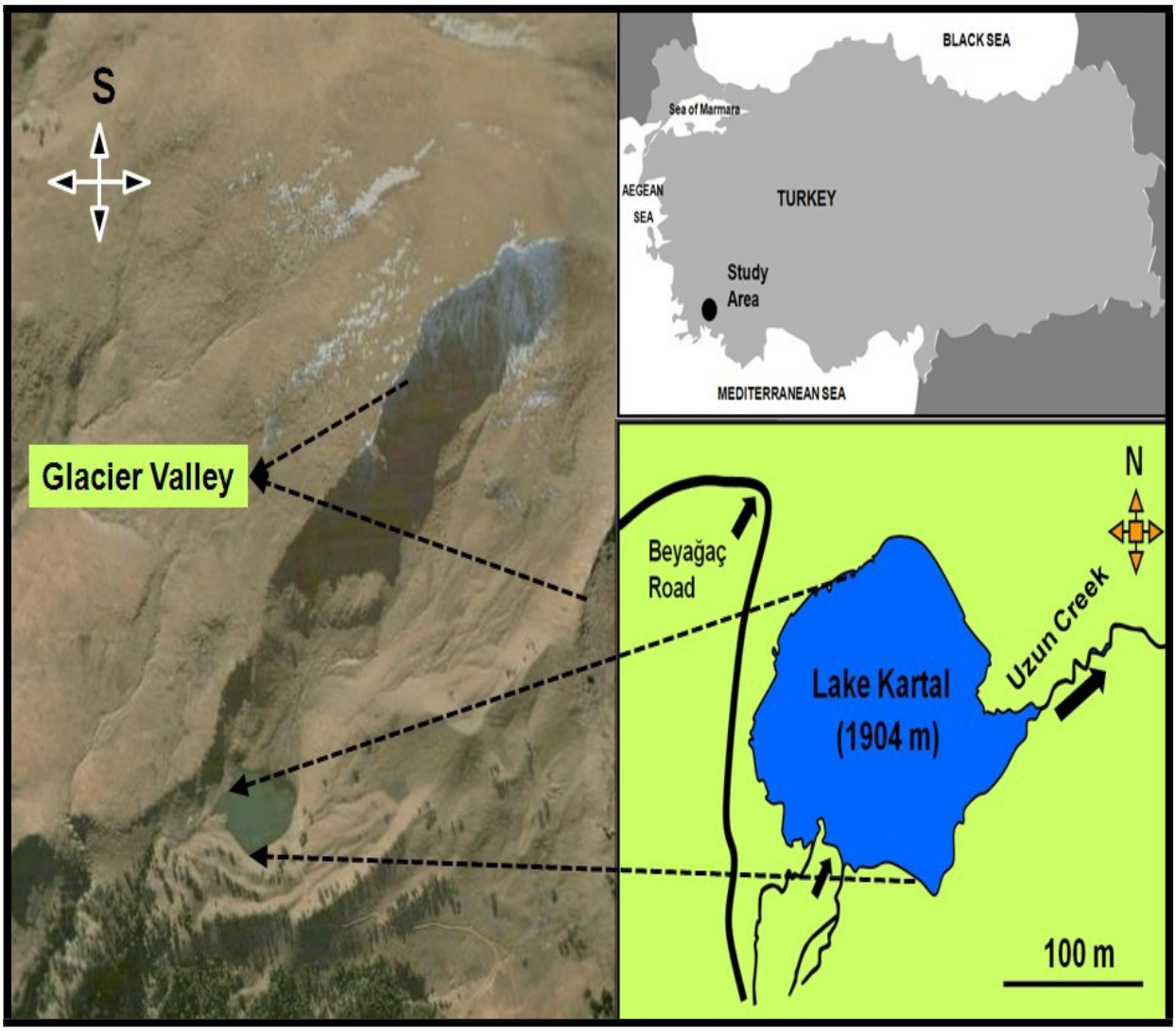

Fig 1: Location of Lake Kartal (closed circle= study site). Digital image is produced from Google Earth 4.3.

2.2 Sampling and qualitative analysis of Ostracoda and accompanying fauna

Microcrustacean samples were collected from Lake Kartal during the ice-free periods of (May-October) 2008. Ostracods were sampled by means of an Ekman grab (225 cm^2) and fixed in the field in 4% formaldehyde. In the laboratory, ostracods were separated from sediment using four standardized sieves (2.0, 1.5, 0.5, 0.25 mm mesh size, respectively). Samples were stored in 1:1 70% ethanol: glycerine, and species identification was made on the basis of both soft parts and carapace-based characters using standard keys [11, 12] but with systematic nomenclature following Meisch [12] and Hartmann and Puri [13] Accompanying fauna to the ostracods were two copepod taxa (*Paracyclops fimbriatus* (Fischer 1853), *Diacyclops bicuspidatus* (Claus 1857) and two taxa of cladoceran (*Simocephalus exspinosus* (Koch 1841), *Alona quadrangularis* (O.F. Müller 1785). The cladocerans and copepod samples were collected with a 55 µm mesh size plankton hand net, taking both horizontal and vertical hauls.100 litters of water was filtered using plankton net (55 µm mesh size) fitted with a glass bottle of 500 ml capacity. A retentate containing different zooplanktons was preserved after collection in neutral formalin 4%. For taxonomical identification of the specimens the keys by Margaritora [14], Negrea [15] and Smirnov [16] for Cladocera, Dussart [17, 18], Harding and Smith [19] and Kiefer [20] for Copepoda were used.

Fig 2: Glacier valley and Lake Kartal

2.3 Analysis of physico-chemical variables:

The main physicochemical parameters, such as temperature (T_w), salinity (‰), pH, dissolved oxygen (mg/L), electrical conductivity (µS cm^{-1}) were measured with hand held model WTW 340i multi-meter equipment *in situ*. Water transparency was measured with a 25 cm diameter Secchi disk.

2.4 Statistical analysis

Correlation was studied with a two-tailed nonparametric Spearman Correlation analysis performed with SPSS 10.0 software program [21]. Significant results were determined at 0.01 and/or 0.05 critical levels. Bray-Curtis similarity analysis of the cladoceran, ostracod and copepod species in the five lakes (Lake Kartal; Lake Karagöl (Beyağaç); Saklıgöl; Karagöl (Bozkurt), Yayla (Süleymanlı); Saklıgöl) was conducted using the Multivariate Statistical Package [21].

3. Results and Discussion

The microcrustacean fauna diversity of Lake Kartal wetland was determined. About 6 species belonging to 3 different groups - Cladocera (2 species, 1633 individual), Copepoda (2 species, 1666 individual), Ostracoda (2 species, 1337 individual) had been observed. Copepoda and Cladocera mainly targeted mainly groups in this study are not. Hence, more detailed informations were not presented about the species belonging to these groups by us. According to results, the lake water was alkaline throughout the year. The water salinity ranged between 0.0-01 ‰, the peak being observed during July and August. It was found to be well oxygenated with DO ranging from 6.9-7.9 mg/L. Individual numbers of ostracods and other microcrustacean species and their frequency are shown in Table 1 and Fig 3. Seasonal fluctuations in the physicochemical variables and ostracod species are given in Table 2 and Fig 4.

Table 1: Numbers of individual of ostracods and other microcrustacean species, and their frequency

Taxa	Sample number (n)	Frequency (%)
OSTRACODA		
Candona neglecta	912	56
Psychrodromus olivaceus	721	44
Total Individual Number	1633	35
COPEPODA		
Diacyclops bicuspidatus	921	55
Paracyclops fimbriatus	745	45
Total Individual Number	1666	36
CLADOCERA		
Alona quadrangularis	788	59
Simocephalus exspinosus	549	41
Total Individual Number	1337	29

Table 2: Seasonal fluctuations in physico-chemical parameters and ostracod species (Abbrevations: **DO:** Dissolved oxygen, **EC:** Electrical conductivity, **T(w):** Water temperature; **CN:** *Candona neglecta*; **PO:** *Psychrodromus olivaceus*; **Max:** Maximum, **Min:** Minimum)

Physicochemical variables	May. 08	Jun. 08	Jul. 08	Aug. 08	Sept 08	Oct. 08	Mean	Max.	Min.
T(w) (°C)	17	21	24	20	15	10	17.8	24	10
Salinity (‰)	0	0	0.1	0.1	0	0	0.03	0.1	0
EC (µS cm^{-1})	85	95	98	104	110	94	97.6	110	85
pH	8	8.25	8.56	8.72	8.94	8.4	8.47	8.94	8
DO (mg/L)	7.5	7.3	7.9	7.5	6.9	7.8	7.48	7.9	6.9
CN	160	321	180	156	70	25	152	321	25
PO	136	254	140	120	60	11	120	254	11

Kartal lake is a freshwater (0.0-0.1‰) and alkaline (pH = 8.0-8.94) lake. The water in Lake Kartal is similar to oxygen-rich (6.9-7.9 mg/L) and fast-flowing water such as rivers. Secchi disk was visible to the bottom of lake with transparency 2 m (max. depth). Secchi depth therefore corresponds to water depth.

According to Spearman correlation analysis (Table 3), there was significant positive relationship between ostracod species and temperature in Lake Kartal. Ostracoda fauna of Lake Kartal compared with other four adjacent lakes see that there were significant negatively relationships between number of ostracod species and altitude in Lake Kartal (see Fig 5)

Table 3: Spearman rank correlation showing significant relationships between ostracod species and environmental variables. For abbrevations see Table 2. High correlations are indicated in bold face (*p<0.05, **p<0.01) n.s: not significant

	T(w)	SAL.	pH	DO	CN	PO
T(w)	**1**					
SAL.	0,621	**1**				
PH	-0,086	0,414	**1**			
DO	0,232	0,525	-0,203	**1**		
CN	**0,886 (*)**	0,207	-0,429	n.s.	**1**	
PO	**0,886 (*)**	0,207	-0,429	n.s.	**1,000 (**)**	**1**

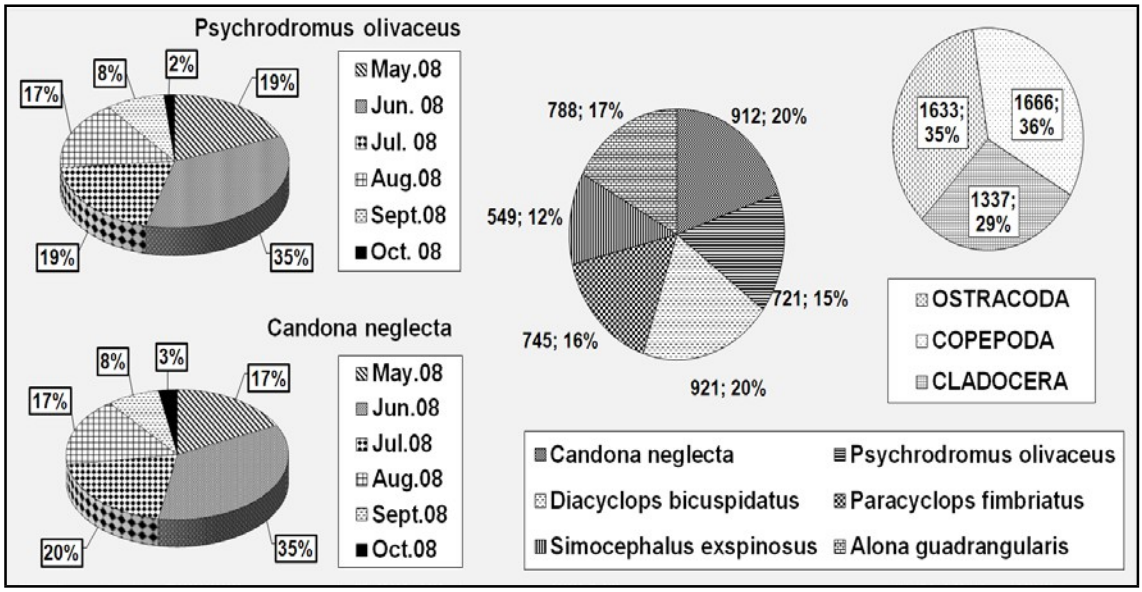

Fig 3: The total number of individuals and percentage in belonging to all determined taxa (Ostracoda, Copepoda and Cladocera), and total number of individuals of ostracod species and percentage rate of individuals

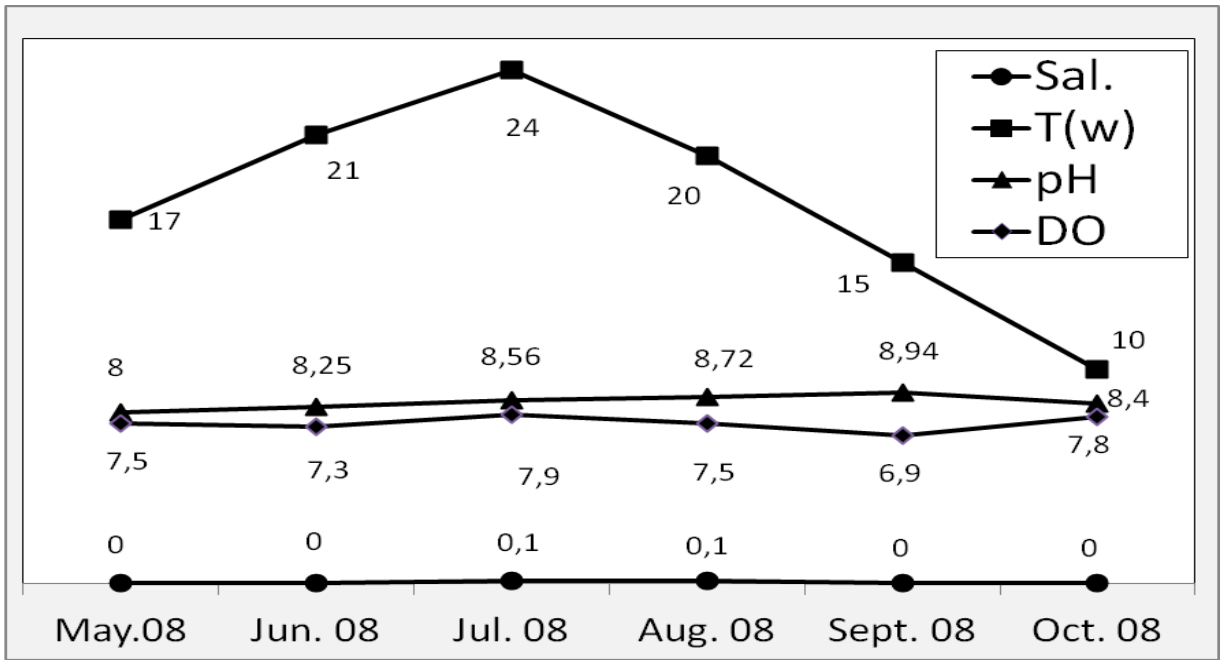

Fig 4: Seasonal fluctuation in physicochemical variables in the lake Kartal (Abbreviations are same as in Table 2)

Sampling was done from lake during May 2008 to October 2008. The sampling site was 1.0 m deep, and muddy with detritus. The accompanying fauna consisted of chironomid larvae, Oligochaeta, bivalvian mollusc, Hemiptera and small fish. The chironomid larvae were the dominant group according to the other macrobenthic groups in the lake. The accompanying flora consisted of filamentous green algae.

The most dominant ostracod species of Lake Kartal was the benthic *C. neglecta* (912 individuals, 56%) followed by *P. olivaceus* (721 individuals, 44%). *C. neglecta* was recorded from springs streams, and a variety standing waters, including both fresh and brackish water in Turkey [22]. The most significant records (showing the presence of this species in the 43 major lakes of Turkey) for this species was given by Altınsaçlı [2]. Its distributional record was given from Europe, North Africa, Asia and North America (Holarctic) [12]. *C. neglecta* is known to have cosmopolitan characteristics, found in wide ranges of geographic area within a variety of habitats. It was reported up to an altitude of 1937m a.s.l. in the Alps [23], and in springs up to 2160 m a.s.l in the Pyrenees [24, 25]. It is one of the dominant species in Pyrenean springs [25]. *C. neglecta* is a cold stenothermal and oligothermophilic species [24] and with a wide tolerance to cold and organically rich habitats [26]. However, it was found in the warmer waters of the lake in summer in this study. *C. neglecta* was found in the eight lakes (altitudes between 1100-3120 m a.s.l.) on the Kaçkar Mountains by Aygen *et al.* [8]. It is a common species in freshwater, but it was reported from slightly salty inland and coastal water within a salinity range of 0.5-16‰ [2, 12]; it has been reported from brackish water in Turkey [2]. *C. neglecta* is oligothermophilic, mesorheophilic, titanoeuryplastic, euryplastic, polytitanophilic, mesohalophilic and poly-halophilic [12, 27, 28, 29]. *C. neglecta* can also tolerate very low oxygen concentrations during the summer [12]. During the summer months, low dissolved oxygen levels were not determined in the Lake Kartal. This condition may be illustrated with presence of filamentous green algae, phytoplankton organisms and well oxygenated cold snow and ice waters flowing into the lake.

P. olivaceus was firstly recorded in Turkey by Hartmann [30]. In addition, the most significant records (showing the presence of this species in the 14 lakes) for this species was given by Altınsaçlı [2]. It was reported up to an altitude of 1307-1700 m a.s.l. in a spring of the Jura Mountains in Switzerland by Wolf [31]. It is oligo thermophilic, mesorheophilic, euryplastic for substrate [32]. Its distributional record was given from Europe [12] and Pyrenean springs [24]. *P. olivaceus* was common in all types of springs. During this study, shells of *P. fontinalis* (Wolf, 1920) that belong to *Psychrodromus* genus were frequently encountered in Lake Kartal.

There are high positive correlations between the two ostracod species. Because, *P. olivaceus* and *C. neglecta* can coexist in similar ecological conditions and same habitats. As spring waters pools habitats are frequently preferred by the *P. olivaceus and C. neglecta* [2, 12, 22]. Lake Kartal is very similar to pools of spring waters with all of the features. Therefore, P. olivaceus and C. neglecta were found in circumstances appropriate to the predetermined ecological characteristics in this study [2, 12, 22].

Cladocerans form a typical limnic group. They are important food for planktivorous fish and other zooplanktonic predators. 549 individual of *S. exspinosus* were found in the lake. 788 individuals of *A. quadrangularis* were found in the lake. The most dominant common cladoceran species of Lake Kartal was the *A. quadrangularis* (59%) followed by *S. exspinosus* (41%). Both of cladoceran species were found in circumstances appropriate to the ecological characteristics in this study.

As for the copepods, the dominant species in the Lake Kartal was the *D. bicuspidatus* (55%) followed by *P. fimbriatus* (45%). 921 individuals of *D. bicuspidatus* were found in the lake. 745 individuals of *P. fimbriatus* were found in the lake. *D. bicuspidatus* and *P. fimbriatus* were found in circumstances appropriate to the predetermined ecological characteristics in this study.

Detritus was accumulated at the lake bottom. Therefore, the bottom of Lake Kartal is covered in mud. A rich muddy lake bottom is appropriate for the benthic species like *A. quadrangularis*, *C. neglecta* and *P. olivaceus*.

Rates of dominance belonging to all microcrustacean taxa are

shown in Fig 3. Microcrustacean species have been determined belonging to Cladocera, Copepoda and Ostracoda taxa from the adjacent lakes Karagöl (Beyağaç, District), Saklıgöl (Honaz District), Karagöl (Bozkurt District) and Yayla (Süleymanlı) (Buldan District) located in the upland area of Denizli Province.

Microcrustacean (Ostracoda, Cladocera and Copepoda) species list recorded in five lakes (see Table 4). Aquatic macrophytes are available in the Lakes Yayla (Süleymanlı), Karagöl (Beyağaç), Saklıgöl and Karagöl (Bozkurt). Temperature, lake size, absence of aquatic flora and high altitude are important factors affecting distribution of ostracod and other accompanying fauna in Lake Kartal and adjacent lakes. Lake Kartal microcrustacean fauna was compared with other adjacent highland lakes. The importance of altitude as a limiting factor on freshwater ostracod species in mountain lakes is shown in Fig 5.

Table 4: List of Cladocera, Copepoda and Ostracoda species known from Lake Kartal and other highland lakes in adjacent area. (Abbrevations: LK: Lake Kartal; LKAB: Lake Karagöl (Beyağaç); LS: Lake Saklıgöl; LKB: Lake Karagöl (Bozkurt) and LY: Yayla (Süleymanlı)

TAXA	LK	LY	LS	LKB	LKAB
OSTRACODA	This study	Altınsaçlı [2]	Altınsaçlı [2]	Altınsaçlı [2]	Altınsaçlı [2]
Candona neglecta G.O. Sars 1887	•	•	•		
Pseudocandona marchica (Hartwig 1899)				•	
Ilyocypris biplicata (Koch 1838)		•			
Ilyocypris bradyi G. O. Sars, 1890			•	•	
Ilyocypris monstrifica (Norman 1862)		•			
Cypris pubera O.F. Müller 1776		•		•	•
Eucypris mareotica (Fischer 1855)			•		
Eucypris virens (Jurine, 1820)		•			
Prionocypris zenkeri (Chyzer&Toth 1858)				•	
Heterocypris incongruens (Ramdohr, 1808)		•			
Heterocypris salina (Brady, 1868)			•		
Herpetocypris chevreuxi (Sars, 1896)		•			
Psychrodromus olivaceus (Brady&Norman, 1889)	•	•			
Potamocypris variegata (Brady&Norman, 1889)					•
Potamocypris villosa (Jurine 1820)		•			
Paralimnocythere psammophila (Flössner 1965)		•			
COPEPODA	Altınsaçlı (Unpubl. data)	Altınsaçlı (Unpubl. data)	Altınsaçlı (Unpubl. data)	Altınsaçlı (Unpubl. data)	Altınsaçlı (Unpubl. data)
Diacyclops bicuspidatus (Claus, 1857)	•				
Paracyclops fimbriatus (Fischer 1853)	•				•
Canthocamptus microstaphylinus Wolf 1905		•	•	•	
Acanthocyclops viridis (Jurine 1820)		•	•	•	
Acanthocyclops robustus (Sars 1863)		•	•	•	
Macrocyclops albidus (Jurine 1820)			•	•	
Cyclops strenuus Fischer, 1851		•	•	•	•
Eucyclops serrulatus (Fischer, 1851)		•	•	•	•
CLADOCERA	Altınsaçlı (Unpubl. data)	Altınsaçlı(Unpubl. data)	Altınsaçlı (Unpubl. data)	Altınsaçlı (Unpubl. data)	Altınsaçlı (Unpubl. data)
Alona quadrangularis (O. F. Müller 1785)	•				
Simocephalus exspinosus (De Geer 1778)	•	•	•	•	
Simocephalus vetulus (O.F. Müller, 1776)		•	•	•	
Ceriodaphnia quadrangula (O.F. Müller 1785)		•			
Ceriodaphnia reticulata (Jurine 1820)		•	•	•	
Daphnia curvirostris Eylmann 1887		•	•	•	
Daphnia longispina O.F. Müller 1785		•	•	•	•
Ilyocryptus agilis Kurz 1878,		•			
Ilyocryptus sordidus (Lievin 1848)		•			
Acroperus harpae (Baird, 1834)		•			
Mbina micrura Kurz, 1874		•	•	•	•
Macrothrix hirsuticornis Norman Brady 1867		•	•	•	
Chydorus sphaericus (O.F. Müller 1776)		•	•	•	•
Leydigia acanthocercoides (Fischer 1854)		•			

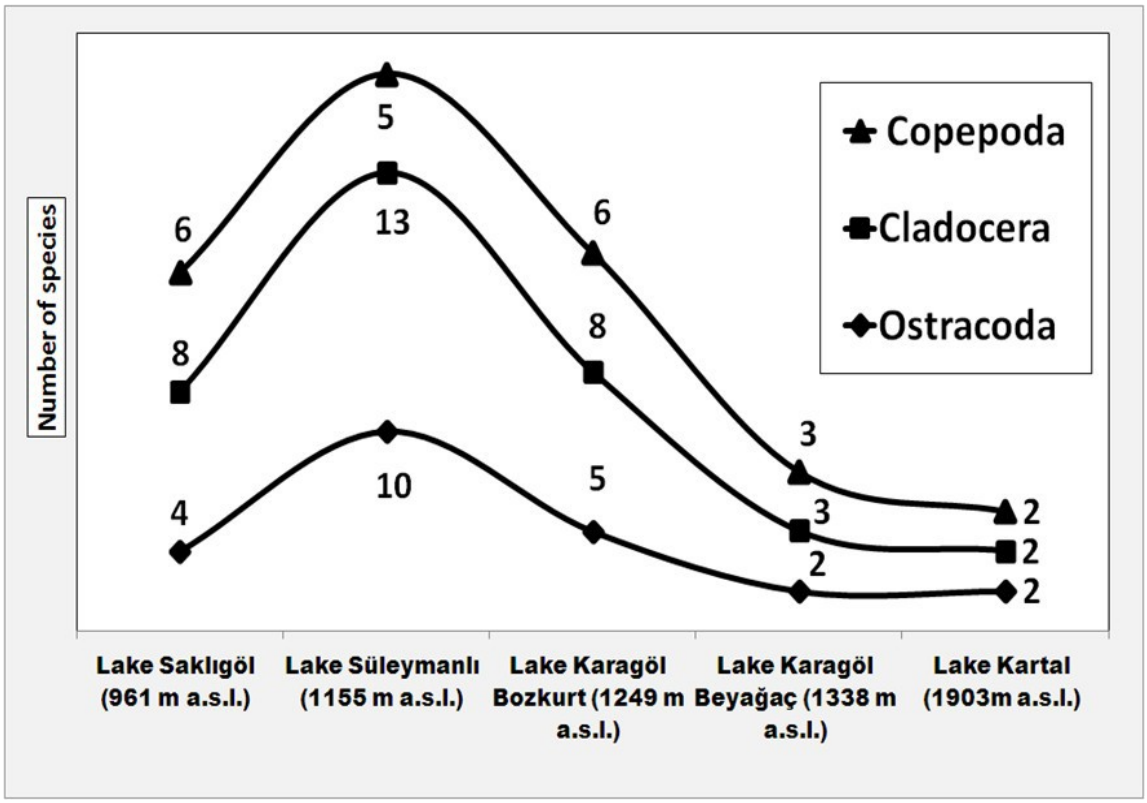

Fig 5: The importance of altitude as a limiting factor on microcrustacean fauna in Lake Kartal and other adjacent highland lakes.

Similarity rates of Ostracoda, Cladocera and Copepoda fauna of Lake Kartal and other lakes were compared and are given in Fig 6.

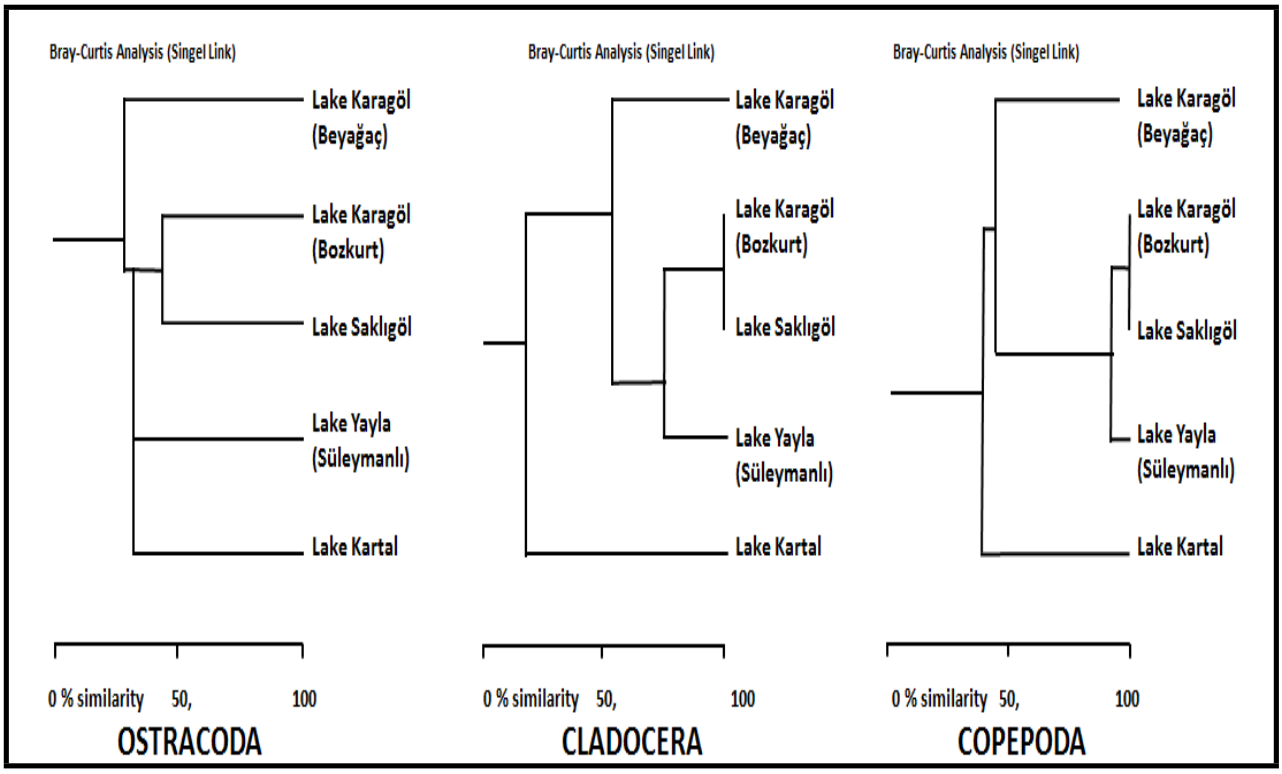

Fig 6: Dendogram according to Bray-Curtis Index of Similarity for the five lakes studied. Dendogram is showing Bray-Curtis Index of Similarity of cladoceran, ostracod and copepod species composition of the five lakes.

Ostracoda fauna of the Lake Kartal shows low similarity with the Ostracoda fauna of other adjacent lakes (see Fig 6). Physico-chemical characteristics of Lake Kartal show that it is oligotrophic with good water quality. Evergreen alpine grasses around the lake serve as grassland for animal breeders. Therefore, a large number of peasants carry bovine animals and small cattle to the surrounding pastures of the lake for grazing. These animals' droppings reach lake water in summer months thus increasing, nitrate, nitrite and phosphorous levels. At the end of the summer, the blue water of the lake becomes greenish. The trophic level of the lake does not change too much during arid summer period. Because, lake is fed with melting snow water from summer until autumn. Therefore, falling lake water-levels were not determined during in arid season. Nutrient salts were discharged by Uzun Creek in all seasons. For this reason, release of nutrient salts is inhibited from lake sediments. High altitude and latitude lakes are usually poor in their species assemblages due to extremely harsh physical characteristics, because low annual and summer temperatures, short ice-free periods, and low habitat diversity restrict the number of successful colonizers. Parallel to this information, we have identified poor microcrustacean fauna in this lake compared to lowland lakes. Solar UV-radiation has a strong effect on Alpine lakes due to thinner atmosphere and higher water transparency than in lowland lakes [33]. UV-exposure in transparent alpine lakes is strongly related to water depth, and decreases with increasing water depth [33]. The Secchi Disk depth was 2 m, down to the deepest location in the lake.

Low temperature values were not determined in the summer period. Nevertheless it must be great differences between day and night temperatures of the Lake Kartal. Temperature and absence of macrophyte assemblages are the most important negatively affecting factors to biodiversity and species richness in Lake Kartal.

However, altitude has a negative relationship with species richness and diversity. The importance of altitude as a limiting factor on freshwater ostracods in Spanish waters was argued by Mezquita *et al.* [34]. This situation is confirmed by ostracod poor Holocene sediments of glacial lakes located on Mount Uludağ [7]. Also, Akçer *et al.* [7] determined single ostracod species in the Holocene sediments one of the glacial lakes of Uludağ Mountain. Population density of the ostracod species is negatively affected by speed of water flow. Generally, species richness and diversity are low in lotic aquatic systems. Overflowing waters of the lake Kartal flows to outlet of lake in all the seasons although lake is covered with ice in autumn winter and spring months.

Lake Kartal is a rare glacier lake in the western part of the Taurus Mountains, it is important evidence of the past glacier activities of last ice age, and also it is a very important ecological and geographical natural heritage for the world. Lake deposits there include records relating to fauna and flora of the last glacial age. Therefore, the paleoecological importance of the lake is increased for scientific studies. The lake must be protected with effectual and stringent precautions by official authorities. As proposed for other Turkish lakes by researchers, such bio-monitoring studies as sample collection and analysis of environmental data should be used in Lake Kartal. The results of this study may help to evaluate future changes in the lake ecology, establish the importance of the lake and make a contribution to the lake management by researchers and administrative authorities. Lake investigations can provide valuable ecological information to researchers for understand environmental changes. Also, obtained data on the biotic and abiotic factors and indicator species are used for interpretations of comparative ecological studies.

4. Conclusions

The results of the present study on the Ostracoda and zooplankton community and other ecological variables may help to evaluate future changes in the lake ecology and make contribution to the lake management. Finally, we are summarized our findings on Ostracoda fauna of Lake Kartal as follows:

1. We collected 1633 ostracod specimens in Lake Kartal and identified them into two species.
2. Two ostracod species (*CN, PO*) were found in freshwater.
3. We determined that the water temperature and altitude were the most important environmental variable affecting ostracod species distribution.
4. Two ostracod species (*CN, PO)* have strong positive correlation with the water temperature, and weak negatively correlation with the pH. Two ostracod species (*CN, PO)* have strong positive correlation
5. The ostracod abundance increases in during the warm spring-summer period due to increased water temperatures. Their maximum abundance seems in June.
6. Kartal Lake can be characterized as an oligotrophic perennial lake due to its nutrient poor status. It is also a limnetic lake due to its lack of rooted vegetation.
7. We may conclude that limnological and faunistic data of Lake Kartal given in present study. However, ecological and faunistic data of the lake must enrich with new studies performed on other faunistic groups in future
8. We may conclude that Lake Kartal has real and important ecological problems due to anthropogenic activities. If the authorities will not protect this lake, it will be frequently damaged by human impact.

5. Acknowledgments

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